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ORIGINAL ARTICLE

Neurophysiological characterization of persistent pain after laparoscopic inguinal hernia repair

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Abstract
Purpose About 2–5% of patients undergoing laparoscopic inguinal repair experience persistent pain influencing everyday activities. However, compared with persistent pain after open repair, the combined clinical and neurophysiological characteristics have not been described in detail. Thus, the aim of the study was to describe and classify patients with severe persistent pain after laparoscopic herniorrhaphy.
Methods Eleven patients with severe persistent pain following laparoscopic inguinal herniorrhaphy were assessed in detail by their medical history, questionnaires (impairments of daily activities, pain description, psychological parameters, socio-economic status), physical examination, sensory mapping, and quantitative sensory testing.
Results The median time since operation was 2 years (range 1–14 years). Ten patients experienced pain in the inguinal region and five patients had pain outside the inguinal region. Based upon the clinical pain pattern and the detailed quantitative sensory testing, the patients could be separated into three different entities, suggesting different pathogenic mechanisms leading to the persistent pain state. Four patients experienced dysejaculation. Six patients were unemployed or retired due to the postherniorrhaphy pain.
Conclusions These results suggest that patients with severe persistent pain after laparoscopic inguinal herniorrhaphy belong to distinctive subgroups with indicators of either neuropathic, inflammatory, or mechanical irritation from the mesh, or a combination of these symptoms. The findings of a number of pain localizations outside the inguinal region demarcate it from persistent pain following open groin hernia repair. A classification based on a larger study group is required in order to define mechanism-based treatment strategies.

Keywords Chronic pain · Herniorrhaphy · Laparoscopic surgery · Postoperative pain · Neuropathic pain

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Introduction

Laparoscopic inguinal hernia repair may have advantages in terms of faster postoperative recovery and less expected persistent pain than after open repair [1–6]. However, about 2–5% of patients may still suffer from persistent pain influencing everyday activities, and about 0.4% are referred to pain clinics [7]. To our knowledge, patients with severe persistent pain after laparoscopic herniorrhaphy have not been characterized in detail, including physical examination, psychosocial evaluations, and quantitative sensory testing, similar to data from open groin hernia repair [8, 9]. The aim of this study was, therefore, to describe and characterize severe persistent pain after laparoscopic inguinal herniorrhaphy.

Methods

Males older than 18 years of age with severe persistent pain [10] (>12 months) affecting everyday activities after laparoscopic inguinal herniorrhaphy and referred to our specialist pain clinic after the exclusion of hernia recurrence were included. Previous surgical and medical history were obtained. All patients returned questionnaires during a consultation with a physician, which included a pain interview, physical examination, sensory mapping, and quantitative sensory testing (QST) [8]. No change in analgesic medication was made before the study. The study was approved by the local ethics committee and the Danish Data Protection Agency, and was registered at http://clinicaltrials.gov/ct2/show/NCT01085110.

Pain assessment and other pain-relevant factors, including questionnaires

Pain was assessed on a numerical rating scale (NRS: 0 = no pain, 10 = worst pain imaginable). Severe pain was defined as NRS $\geq$ 7 and moderate pain as NRS = 4–6. Impairment of everyday activities was assessed by the validated Activities Assessment Scale (AAS) [11]. The AAS includes 13 items covering a broad representation of activities of daily living, evaluating to what degree the pain affects each activity, ranging from "1 = no impairment" to "5 = unable to perform the activity". The AAS was divided into four categories (no impairment = 0, minimal impairment = 0–7.7, moderate impairment = 7.7–32.8, severe impairment >32.8) [12]. Anxiety and depression scores were evaluated by a Danish version of the Hospital Anxiety and Depression Scale (HADS) [13].

Sensory mapping

Sensory mapping was assessed with a 25°C metal roll (Thermoroll, Somedic AB, Hörby, Sweden), which was moved over the area at 1–2 cm/s to evaluate and indicate changes in cool sensitivity. The changes were indicated by a marker on the skin and transferred to a transparent sheet following the tests.

QST assessments

Hair was carefully shaved from the inguinal regions with an electrical, surgical trimmer, with a 5–10-min pause to allow the irritation to wear off. The assessment of sensory thresholds was first performed on the lower forearm in order to familiarize the patient with the testing sequence. The tests were made in both inguinal regions [8], with the testing sequence beginning on the pain-free or less painful side. If the patient's pain or an area with sensory changes was located to an area other than the inguinal region, the sensory test was also carried out on the homologous, contralateral side. For areas located in the median area of the abdomen, the comparison was made with the non-pathological inguinal region. The testing area was standardized, corresponding to the area of the thermode (12.5 cm^2) and always included the point or area of maximum pain (indicated by the patient and confirmed by palpations by the investigator). Patients could, at any time, interrupt the stimulus procedures verbally or by activation of the stop button.

Thermal detection and thermal pain thresholds

Thermal thresholds, i.e., warmth detection threshold (WDT), cool detection threshold (CDT), heat pain threshold (HPT), and cold pain threshold (CPT), were assessed by a computerized rectangular thermode (Modular Sensory Analyzer, Somedic AB, Hörby, Sweden) with an area of 12.5 cm^2. The testing was done in triplicate with a randomized inter-stimulus interval of 4–6 s, starting from a baseline temperature of 32.0°C with a ramp rate of $\pm$1.0°C/s. Cut-off limits were 50.0 and 5.0°C, for heat and cold measurements, respectively.

Tactile detection threshold (TDT) and tactile pain threshold (TPT)

The tactile detection threshold (TDT) was determined using monofilaments (Stoelting, IL, USA; nominal buckling force ranging from 0.08 to 2,941.2 mN). The threshold was calculated from the mean of five ascending and five descending stimulus intensities. The smallest fiber leading to tactile detection was registered. The tactile pain threshold (TPT) was assessed by the use of the same stimulus paradigm, but registering the perception of pain (sharpness/sting).

Pressure pain threshold (PPT), pressure pain tolerance (PPTo), pinch pain threshold (PiPT), and pinch pain tolerance (PiPTo)

Deep-tissue pain sensitivity was assessed using a pressure algometer with a neoprene-coated tip of area 1.0 cm^2 (Somedic AB, Hörby, Sweden). The algometer was applied perpendicularly to the skin with a pressure rate of 30 kPa/s until pain was reported or the pressure exceeded 350 kPa (cut-off value). For the pinch pain threshold (PiPT) assessment, compression and squeezing of a skin fold was made with the pressure algometer. Testing was done in triplicate and the average value was calculated, except for tolerance assessments, which were only made once. Pain tolerance was assessed as the maximum tolerable pain or until the pressure exceeded the cut-off value.

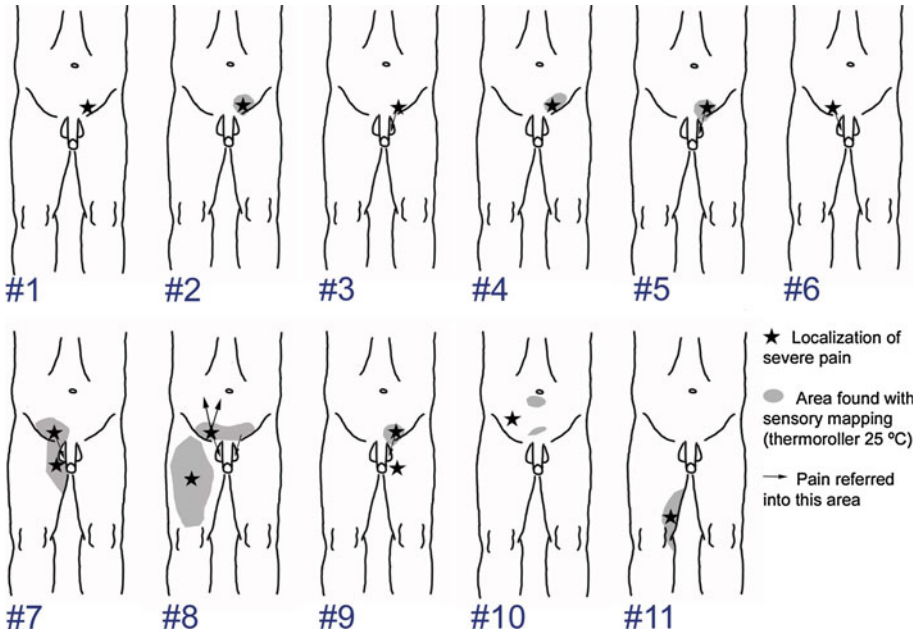

Fig. 1 Areas assessed by sensory mapping, localization of severe pain, and pain projection in 11 patients with persistent pain after laparoscopic inguinal hernia repair

Temporal summation to brush stimulation and pinprick stimulation with a monofilament ("wind-up")

Temporal summation in response to mechanical stimulation was performed with both a brush for dynamic stimulation and a monofilament for pinprick stimulation. The patients were told to describe their experience of pain (NRS) during repeated stimulation at 2 Hz for 60 s. Positive "wind-up" was defined as an increase ≥2 points, with or without after-sensations.

Comparison of QST variables

The criteria for differences between the painful side and the contralateral side or a control site were a priori assigned to the following:

- For warmth and cool detection thresholds: ≥1°C
- For heat and cold pain thresholds: ≥2°C
- For pinprick stimuli (detection and pain thresholds): ≥2 nominal values of monofilaments
- For perpendicular pressure (pain and tolerance thresholds): when the mean values of the two assessments were ≤150 kPa, the required difference was ≥50 kPa, and when the mean values of the two assessments were >150 kPa, the required difference was ≥100 kPa
- For temporal summation: ≥2 NRS values

Results

Eleven patients were examined, with a median age of 43 years (range 23−60 years). The median duration since laparoscopic operation was 2 years (range 1–14 years). All patients had daily pain with a median intensity of resting pain of NRS 5 (range 4–8). The maximum pain intensity was a median of NRS 10 (range 7–10) and appeared daily in six patients and weekly in five patients (Table 1). The anatomical location of the pain is illustrated in Fig. 1.

Surgical history

The laparoscopic operations were all elective and transabdominal pre-peritoneal (TAPP) procedures. All patients recalled severe acute pain immediately after the operation, except for two patients (#4, #8). Four patients (#1, #2, #4, #10) had an open herniorrhaphy prior to the laparoscopic operation. Two patients (#5, #7) had an open herniorrhaphy after the laparoscopic operation. Three patients (#3, #6, #11) had only the laparoscopic operation. The open herniorrhaphies were not associated with the development of persistent pain.

Influence of persistent pain on daily activities and socio-economic conditions

All patients had pain-related impairment of everyday activities, with a median AAS score of 52% (range 21–67, Table 1). All patients, except one (#11), had severe impairment of everyday activities. The impairment varied from mainly physical activities to non-physical activities, such as sitting and lying down in the supine position. Two patients experienced severe pain when lying down (Table 1). Only two patients (#5, #8) were able to work and one patient (#9) was a student. Six patients (#1– #4, #7, #10) were either on sick leave, unemployed, or were prematurely retired due to postherniorrhaphy pain. One patient (#11) was on sick

Table 1 Descriptive data of 11 patients with severe persistent pain after laparoscopic hernia repair

Patient no. (1–11)	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
Group I–III[a]	I	II	III	I	II	III	I	III	II	III	–
Side of operation (BL = bilateral, UL = unilateral)	UL	UL	BL	UL	BL	UL	BL	BL	BL	UL	BL
Severe pain (NRS > 7)	Daily	Weekly	Weekly	Weekly	Daily	Weekly	Daily	Daily	Daily	Weekly	Daily
Maximum pain (NRS)	9	10	7	8	10	10	10	10	7	10	9
Ejaculatory pain	−	−	−	−	+	+	−	+	−	+	−
Pain-related impairment of mild physical activities, such as cooking, office work, visiting friends	Moderate	Severe	Severe	Moderate	Mild	Moderate	Moderate	Severe	Mild	Mild	No
Pain-related impairment of moderate physical activities, such as cleaning, dancing, washing car	Moderate	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Mild	Mild	No
Pain when sitting	Severe	Severe	Severe	Mild	Mild	Severe	Moderate	Severe	Moderate	Moderate	Mild
Pain when laying in bed	Mild	Severe	Mild	Mild	No	Mild	Moderate	Moderate	Severe	Moderate	Mild
Total AAS score (median): 0% if no pain to 100% for maximum impairment	56% (severe)	65% (severe)	42% (severe)	52% (severe)	33% (severe)	63% (severe)	58% (severe)	67% (severe)	33% (severe)	33% (severe)	21% (moderate)
Non-surgery-related pain in other parts of the body	+	+	−	−	−	+	−	+	−	+	+
Severe pain immediately after the laparoscopic surgery	+	+	+	+	−	+	−	+	+	+	+
HADS scores (depression/anxiety)[b]	−/unlikely	Unlikely/ unlikely	+/+	Unlikely/ unlikely	−/−	−/−	−/unlikely	+/−	−/unlikely	+/+	−/−
Analgesics[c]	WA, SA	No	WO, WA	WA	No	WO, WA	No	SA	No	SA, WO	WA

[a] Based on quantitative sensory testing (QST) data in patients with pain in the inguinal region

[b] Hospital Anxiety and Depression Scale (HADS) questionnaire (Danish version)

[c] Analgesics taken on a weekly basis: *WA* weak analgesics (paracetamol, non-steroidal anti-inflammatory drugs [NSAIDs]), *WO* weak opioids, *SO* strong opioids, *SA* secondary analgesics (antidepressants, anticonvulsants)

leave and another (#6) was on early retirement, both due to other pain-related causes.

Pain-related sexual dysfunction

Pain related to sexual activity occurred in eight patients, with four patients experiencing dysejaculation (Table 1). Six patients experienced pain every time during sexual activity and two patients had recurring pain at every second or third time of sexual activity. Three patients rated the sexual pain as NRS 10. One patient had erectile dysfunction after the laparoscopic herniorrhaphy.

Psychological status

One patient had a previous history of depression. This patient and two other patients had depression and/or anxiety scores above the normal ranges, evaluated by HADS.

Other pain conditions

Two patients had previously experienced severe persistent pain following a surgical procedure not related to the lower abdomen, and six experienced pain from other parts of the body (head, back, knee, hands). However, the post-herniorrhaphy pain was the major cause of physical impairment in all cases, except in one patient with migraine (#10).

Sensory mapping inside and outside the inguinal region

The areas having changes found with sensory mapping are illustrated in Fig. 1. These areas were located in the thigh (#7, #8, #11), abdomen (#10), or the inguinal region (#2, #4, #5, #7, #8, #9). Four of the patients (#7–#10) had changes found with sensory mapping outside the inguinal region in addition to experiencing pain inside the inguinal region.

QST assessments in the inguinal region

From the QST data, the patients were separated into three groups, denoted I–III (Table 2):

- In group I, including three patients (#1, #4, #7 [Table 2]), the primary abnormalities were a decreased pressure pain threshold (PPT) or/and pressure pain tolerance (PPTo) on the painful side, indicating a deep-tissue sensitivity. In patients #4 and #7, there was also demonstrated a reduced pinch pain threshold (PiPT).
- In group II, including three patients (#2, #5, #9), the primary abnormalities were cutaneous hypoaesthesia or hypoalgesia to $\geq$3 of 4 thermal stimulations (WDT, CDT, HPT, CPT) and to $\geq$1 of 2 pinprick stimulations (TDT, TPT), demonstrated on the painful side (Table 2). These patients did not demonstrate any change on the painful side compared to the contralateral side in regard to indicators of deep-tissue sensitivity, such as pressure pain threshold (PPT) and pressure pain tolerance (PPTo). Two of the patients (#2, #5) did not demonstrate any change in pinch pain tolerance (PiPTo), while one patient (#9) had a reduced pinch pain tolerance (PiPTo).
- In group III, including four patients (#3, #6, #8, #10), all had a heterogenous response, with hypo- or hyperalgesia to cutaneous stimulation and general absence of response to deep-tissue stimulation. One patient (#10) demonstrated an increased pinch pain threshold (PiPT).

One patient (#11) did not demonstrate any abnormality in the inguinal region and could not, therefore, be categorized.

There was no apparent asymmetry in the distribution of temporal summation data (brush stimulation [WUB], monofilament stimulation [WUM], or after-sensations) between the groups.

QST assessments outside the inguinal region

QST assessments from the painful side, compared to the contralateral side, or the non-painful inguinal region (#10), are shown in Table 3 (n = 5). No signs of deep-tissue sensitivity were observed in any of the patients in the pressure pain threshold (PPT), pressure pain tolerance (PPTo), and pinch pain tolerance (PiPTo). In regard to the pinch pain threshold (PiPT), only one patient (#11) demonstrated a change, i.e., a reduction in the threshold. In regard to cutaneous stimuli, two patients (#8, #11) showed consistent hypoaesthesia and hypoalgesia to thermal stimulations (WDT, CDT, HPT, CPT).

The sensory abnormalities in individual patients were as follows (Fig. 1):

- In patient #7, the sensory mapping showed cool hyperaesthesia of the upper medial part of the right thigh, but the only QST finding was a reduced heat pain threshold (HPT) with no obvious explanation of a specific cause.
- In patient #8, the sensory mapping showed a large area anteriorly on the right thigh with cool hypoaesthesia. The QST data corroborated the diagnosis of neuropathy, most likely of the anterior cutaneous femoris nerves (branches from the femoral nerve).
- In patient #9, with a localized pain in the upper medial part of the left thigh appearing immediately postoperatively, a partial denervation of the medial head of the quadriceps muscle was diagnosed by electromyography. The QST data could tentatively support a diagnosis of neuropathy, thus, presumably of the anterior cutaneous femoris nerves (branches from the femoral nerves).

Table 2 Data from quantitative sensory testing (QST) in the inguinal areas in patients with severe persistent pain after laparoscopic hernia repair ($n = 11$). Assessments are indicated as the difference between the painful side and the contralateral side

Patient #	1	2	3	4	5	6	7	8[a]	9	10	11[b]
Thermal stimuli											
Δ warmth detection threshold (WDT)	0	↑	0	↑	↑	0	0	↓	↑	↑	–
Δ cool detection threshold (CDT)	0	↑	↓	↑	↑	0	0	↑	↑	0	–
Δ heat pain threshold (HPT)	0	↑	↓	↑	↑	↓	↓	0	↑	↑	–
Δ cold pain threshold (CPT)	0	↑	0	↓	0	↓	↑	0	↑	0	–
Mechanical stimuli											
Pinprick stimuli											
Δ tactile detection threshold (TDT)	0	↑	0	0	↑	↑	0	0	0	0	–
Δ tactile pain threshold (TPT)	↑	↑	0	0	0	0	↓	↑	↑	↓	–
Perpendicular pressure stimuli											
Δ pressure pain threshold (PPT)	0	0	0	↓	0	0	↓	0	0	0	–
Δ pressure pain tolerance (PPTo)	↓	0	0	↓	0	0	0	0	0	0	–
Pinch stimuli											
Δ pinch pain threshold (PiPT)	0	0	0	↓	0	0	↓	0	0	0	–
Δ pinch pain tolerance (PiPTo)	0	0	0	0	0	0	0	0	↓	↑	–
Temporal summation											
Δ brush stimulation[c] (WUB)	0	0	0	↑	0	0	↑	0	0	0	–
Δ monofilament stimulation[c] (WUM)	↑	↓	↑	↑	↑	0	↓	↓	0	↓	–
After-sensations	No	No	Bilat	No	Pain	No	Pain	Bilat	No	Pain	–

Group I (patients #1, #4, #7) indicate patients with reduced thresholds in the painful area to perpendicular pressure stimulation, *Group II* (patients #2, #5, #9) indicate patients with increased thresholds in the painful area to thermal stimulation, and *Group III* (patients #3, #6, #8, #10) indicate patients with a heterogenous response to cutaneous stimulation and general absence of response to deep-pressure stimulation. The criteria for significant differences are indicated in the text

The thresholds are indicated as: 0 = no difference between sides, ↓ = reduced threshold on the painful side (hyperaesthesia/allodynia/hyperalgesia), and ↑ = increased threshold on the painful side (hypoaesthesia/hypoalgesia)

The temporal summation values are differences in pain ratings: 0 = no difference, ↓ = reduced perception on the painful side, and ↑ = increased perception on the painful side. Differences in after-sensations are characterized as none (*no*), bilaterally (*bilat*), or on the painful side (*pain*)

[a] The patient had bilateral pain in the inguinal region and the difference was assessed between the most painful side and the contralateral side

[b] Patient #11 did not experience pain in the inguinal region

[c] Comparisons were made with the non-painful inguinal region

- In patient #10, sensory mapping of two small areas near the umbilical and suprapubic region demonstrated cool hypoaesthesia. There was no symmetry in the cutaneous QST data.
- In patient #11 (group IV), a gait affection of the right leg developed during the first week postoperatively. Electromyography showed partial denervation of the right adductor magnus muscle, indicating an injury to the obturator nerve. The sensory mapping demonstrated an area with cool allodynia on the medial side of the thigh above the knee. The QST data also supported the diagnosis of neuropathy, presumably of the obturator nerve.

Discussion

Persistent pain after laparoscopic inguinal hernia repair can be severe, and may have a profound effect on daily activities and quality of life. In the present first detailed descriptive study, all patients had either severe daily pain or severe impairment of daily activities due to pain. The development of pain after groin hernia repair may be influenced by both surgical (nerve damage, inflammation, mechanical irritation of the mesh) and individual factors (genetics, sensory, psychosocial) [14–16]. The role of psychological factors in the three patients with pathological scores on depression or anxiety scores cannot be evaluated, since we had no psychological data before the previous laparoscopic operation, and it remains unclear whether the pain contributes to the depression or the depression contributes to the pain. However, data from open hernia groin repair suggest that preoperative signs of depression/anxiety are not common predictive factors for the development of persistent pain [12]. Six patients were unemployed or retired due to the postherniorrhaphy pain, showing that pain has considerable socioeconomic impact, since many of these patients were young and in work before the surgical procedure.

Table 3 Data from quantitative sensory testing (QST) outside the inguinal areas ($n = 5$) in patients with severe persistent pain after laparoscopic hernia repair. Assessments are indicated as the difference between the painful side and the contralateral side or the non-painful inguinal region as the control. The criteria for significant differences between observations as well as signs and abbreviations are indicated in Table 2. None of the patients demonstrated changes in thresholds to perpendicular pressure stimulation and only one patient (#11) demonstrated a reduced threshold to pinch stimulation. Two patients (#8, #11) showed a consistent increase in thermal thresholds

Patient #	7	8	9	10[a]		11
Pain localization	Thigh medial-proximal	Thigh anterior	Thigh medial-proximal	Suprapubic area	Umbilical area	Thigh medial-distal
Thermal stimuli						
Δ warmth detection threshold (WDT)	0	↑	0	0	↑	↑
Δ cool detection threshold (CDT)	0	↑	0	↓	↓	↑
Δ heat pain threshold (HPT)	↓	↑	↑	0	0	↑
Δ cold pain threshold (CPT)	0	↑	↑	↓	↓	0
Mechanical stimuli						
Pinprick stimuli						
Δ tactile detection threshold (TDT)	0	↑	↓	↓	0	↑
Δ tactile pain threshold (TPT)	0	0	↑	↓	↑	↓
Perpendicular pressure stimuli						
Δ pressure pain threshold (PPT)	0	0	0	0	0	0
Δ pressure pain tolerance (PPTo)	0	0	0	0	0	0
Pinch stimuli						
Δ pinch pain threshold (PiPT)	0	0	0	0	0	↓
Δ pinch pain tolerance (PiPTo)	0	0	0	0	0	0
Temporal summation						
Δ brush stimulation (WUB)	0	0	0	0	↑	↑
Δ monofilament stimulation (WUM)	0	↓	↑	0	↓	0
After-sensations	No	No	No	No	Pain	Pain

[a] Comparisons were made with the non-painful inguinal region

Previous studies have reported that about 4% of patients who have had open groin hernia repair had ejaculatory-related pain [17], which may be associated with pathology involving the vas deferens. Using endoscopic techniques, the handling and contact with the ductus deferens are obviously different compared to the open approach, since the duct does not traverse a slit in the mesh, which may reduce the likelihood of damage and, thereby, ejaculatory pain. Nevertheless, ejaculatory pain was present in four of the patients after the laparoscopic procedure in our study. Future studies are needed to clarify this important issue, but, overall, the incidence is 2% after laparoscopy (unpublished observations).

Most studies suggesting nerve damage in chronic pain patients after laparoscopic repair lack detailed methodological information on how this conclusion was made [18, 19]. Questionnaire studies have reported less pain and groin "numbness" after laparoscopic repair in comparison to an open approach [2, 4, 20, 21]. Detailed neurophysiological assessment in patients with persistent pain after open repair suggests subpopulations with heterogeneous combinations of hypo- and hyperalgesia [8, 9]. To our knowledge, only two studies have included some type of QST assessments in chronic pain patients after laparoscopic herniorrhaphy [12, 22]. One study, of 13 laparoscopically operated patients with mild pain (visual analog scale [VAS, 0–10] score 1.9), only investigated tactile hypoaesthesia with monofilaments [22]. As with "numbness" in the questionnaire studies, hypoaesthesia was related to pain, supporting the observation that nerve damage is a risk factor for persistent pain. Compared with open repair, the hypoaesthesia was distributed over a larger area, was less well defined to the inguinal ligament, and was less intense [22]. In the present study, with a more standardized pain assessment setup and a more detailed QST algorithm, it is reasonable to believe that we had a higher probability of detecting and quantifying changes in our patients [8]. A recent study from a different group of consecutive patients after laparoscopic or open repair found that the HPT was affected in laparoscopically operated patients [12], but without direct correlation with clinical pain. Interestingly, HPT changes in the inguinal region in the present study were observed in 8 of 11 patients.

Although the present study demonstrated pain and sensory heterogeneity among laparoscopically operated patients with severe pain, it was possible to differentiate the patients into subgroups. Among the ten patients with pain in the inguinal region, the three patients in group I (#1, #4, #7, Table 2) were characterized by a reduced pressure pain threshold (PPT [#4, #7]), pressure pain tolerance (PPTo [#1, #4]), and pinch pain threshold (PiPT [#4, #7]) on the painful side. The tests probably reflect deep-tissue sensitivity, where the pain generator could be an ongoing deep inflammation or mechanical irritation of the mesh with or without subsequent damage to nerve structures [8]. However, a neuropathic component cannot be excluded.

In group II, including three patients (#2, #5, #9), hypoaesthesia or hypoalgesia to thermal stimulations and pinprick stimulations were observed on the painful side (Table 2). Interestingly, no changes in the pressure pain threshold (PPT), pressure pain tolerance (PPTo), and pinch pain threshold (PiPT) were demonstrated. The combination of pain, sensory loss, and increased pain detection thresholds to different cutaneous stimuli substantiates a neuropathic pain component. The lack of pressure sensitivity suggests that deep inflammation or a mechanical mesh response is not an active component in the inguinal pain of these patients.

In group III, including four patients (#3, #6, #8, #10), a heterogenous response with hypo and hyper responses to cutaneous stimulation and a general absence of responses to deep-tissue stimulation were seen. The absence of sensory loss does not exclude a nerve lesion [23, 24] and the most probable pathogenic mechanism in this group is a partial nerve lesion.

The individual in group IV (#11) demonstrated that severe pain following laparoscopic hernia repair can be present without inguinal pain or sensory disturbances in the inguinal region.

The five patients (#7–#11 [Table 3]) who had pain in circumscribed areas outside the inguinal region may suggest a neuropathic rather than an inflammatory or mechanical mesh component as the origin of the pain. This is corroborated by the fact that 19 out of 20 tests of the responses to perpendicular or pinch pressure stimuli did not demonstrate any sensory change in these patients, indicating a lack of deep-tissue sensitivity. Although the responses to cutaneous stimuli were generally heterogenous, two patients (#8, #11) demonstrated a fairly uniform increase in the thresholds to thermal stimuli, suggesting a neuropathic component.

There was circumstantial evidence for neuropathic pain in several patients based on both the topographical and the circumscribed pain distribution (#7–#11), electromyography assessments (#9, #11), sensory mapping (#7, #8, #10, #11), and QST assessments (#8, #11). Sensory mapping is a standard neurological assessment test [24] which has been used in a number of hernia studies [8, 25]. Sensory mapping with a 25°C thermoroller covers larger areas than QST abnormalities, but the significance of the differences between the two methods is not known.

The neuropathy could likely be attributed to lesions of the ilioinguinal (#7), femoral (#8, #9), or obturator (#11) nerves. These nerves present a number of anatomical variations, including peripheral communication and an overlapping of the innervation areas [26], making it difficult to make a specific conclusion of which nerve is involved. Our findings are in agreement with previous reports noting that, during stapling of the mesh in laparoscopic hernia repair, there is a risk that the femoral nerve, the lateral femoral cutaneous nerve, and the obturator may become entrapped [18, 19]. The cutaneous branch of the genitofemoral nerve and the lateral femoral cutaneous nerve are suggested to be at the most risk [18]. Three of the patients (#8, #9, #11) had involvement of one of these nerves innervating the thigh. Therefore, it may be important to minimize the number of staples/tacks used for fixation and consider their placement, as well as the potential for glue fixation [12, 27–29].

In our study, one patient (#10) had an area of sensory changes located near the umbilical area, where a trauma after the trocar might be suspected. Alternatively, a stapling procedure distant from the inguinal region may have been performed, since, according to the surgical report, it was a complicated procedure with unintended damage to the peritoneum.

Thus, different combinations of pathogenic mechanisms may be involved in the development of chronic pain after laparoscopic groin hernia repair. However, sensory heterogeneity has been reported in other neuropathic pain disorders, making a distinct pathogenic classification difficult [30]. Temporal summation of pain ("wind-up") was present in eight of the patients, suggesting central nervous system sensitization. However, the relative contribution of peripheral and central sensitization to persistent postoperative pain is unknown [15].

In conclusion, our study suggests that patients with severe persistent pain after laparoscopic inguinal herniorrhaphy may be classified into subgroups according to clinical and neurophysiological data. This calls for an improved pathophysiological, mechanism-based classification which may be relevant for both preventive measures and tailored treatment regimens. Such QST studies will benefit from both larger multicenter study populations and the addition of functional (positron emission tomography [PET] scanning, functional magnetic resonance imaging [fMRI]) and structural (skin biopsies, genetics) analyses [23].

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Conflicts of interest None declared.

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